CONCRETE IN WATER WORKS CONSTRUCTION[1]

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Concrete has been used very extensively in various parts of water supply works such as dams, reservoirs, pipe lines, tanks, standpipes, filters, settling basins, power houses, etc. Obviously, a detailed discussion of all these is beyond the limits of a single paper and it will be necessary to confine the discussion to very general terms in order to take up even a few of these items.

Reservoir linings. For slope wall reservoirs the inclination of the banks is usually from $1\frac{1}{2}:1$ to $2:1$. The thickness of the concrete lining for the slope is from 4 to 8 inches and is usually placed in slabs from 10 to 20 feet square, depending on whether or not the slabs are reinforced. The slabs are usually laid with butt joints with their ends resting on a sill and the space between the ends of the slabs filled with some elastic material to form an expansion joint. Expansion joints between slabs have been very successfully made by caulking with oakum and overlaying the joints with strips of burlap well painted with asphalt.

The Green River storage basin at Tacoma, Wash., was built with expansion joints $\frac{1}{4}$-inch wide at the bottom and $\frac{3}{4}$-inch wide at the top. The sills had tar paper laid on top of them before taking the slabs. The joints were filled with refined asphaltum specified to be pliable between freezing and a temperature of 200°F. and not sticky at 100°F. This joint has proved very satisfactory.

Concrete pressure pipe. Concrete pressure pipe has been successfully used with pressures up to 80 pounds per square inch and there is no doubt but that the pressure which may be handled by concrete pressure pipe is limited only by economy in design and construction.

There are certain requirements which pressure pipe must fulfill, among which are the following: (a), Ability to resist external and

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internal pressures; (b) low coefficient of friction; (c) minimum leakage; (d) low maintenance charges; (e) permanency; (f) provision for contraction and expansion; (g), low cost consistent with the above requirements.

Concrete pressure pipe designed to withstand internal pressure will be found to be strong enough to withstand all ordinary external pressures, as from backfill, to which it will be subjected. Reinforcing steel is, of course, placed in the shell of concrete pipe to assist in withstanding the bursting pressure and some designers use sufficient steel to take the entire bursting pressure. For long lines of large pipe the pipe is constructed in place or at a convenient point near the general location of its use. Thus transportation expenses are low and the manufacture of the pipe can be given continuous inspection. Regardless of whether or not the strength of the concrete itself in tension is taken into consideration in design, it nevertheless does exist and contributes no small part of the actual strength of the pipe. Where it is not considered in the design, this strength of the pipe affords an extra factor of safety.

Correct methods of manufacture will produce concrete pipe with a low coefficient of friction and negligible leakage. A friction test was conducted on the Sooke Lake water supply conduit for the city of Victoria, B. C. The pipe line is of 42 inches diameter, 27½ miles long and contains 50 per cent of curves with radii varying from 90 to 150 feet. There are in the line seven siphons having a maximum head of 94 feet. The tests were conducted by Wynne Meredith, San Francisco manager of Sanderson & Porter, consulting engineers, and the coefficient of friction (n of Kutter's formula) was found to be 0.01058 at the inlet end and 0.0117 at the outlet of the 27½ miles with the pipe running full at the inlet and six-sevenths full at the outlet. With 20 inches of water at the inlet the water level at the outlet was 19½ inches. Some years ago Marx, Wing and Haskins determined from gaugings on a 6-foot steel riveted pipe values of n from 0.013 to 0.018.

The reinforced concrete pressure pipe line constructed as a part of the Gunpowder water supply for the city of Baltimore, Md., consists of 5000 feet of 108-inch diameter pipe and 3000 feet of 84-inch diameter pipe. This line carries 120,000,000 gallons daily and when tested under a head of 85 feet, the leakage in 24 hours on the entire line amounted to 13,000 gallons, or less than two-hundredth of 1 per cent.

Low maintenance on pipe lines must certainly result if the pipe is of such a material that leaks will not develop from corrosion, electrolysis, etc. Concrete, of course, is not subject to corrosion and since concrete pipe must be made sufficiently dense to prevent leakage it follows that the steel reinforcing in the shell of the pipe is perfectly protected so that corrosion of the steel cannot be expected. Of course concrete pipe lines, as well as those of other material, are subject to such accidents as earth slides and cannot be expected to withstand extraordinary conditions under which no type of pipe line would remain intact. The maintenance, however, on a well constructed reinforced concrete pipe line may, with confidence, be expected to be very low.

Permanence is merely a corollary to low maintenance charges. Rust, rot and decay are not defects of concrete pressure pipe and under ordinary conditions, with only the pressures for which the pipe was originally designed and constructed, concrete pressure pipe may be considered as permanent.

Contraction and expansion will occur in pipe of any material and suitable expansion joints must be provided in concrete pressure conduits if the leakage at joints is to be kept at a minimum. Such joints have been developed for use in precast reinforced concrete pipe and have been successful in practice. As the construction of pipe lines is usually done at temperatures higher than that of the water which will flow through the conduit it necessarily follows that contraction will occur. This will produce cracks at the joints through which leakage of considerable amount will occur if provision has not been made to care for the contraction.

An expansion joint that has been found to take care of expansion and contraction consists of a crimped copper band continuous throughout the circumference of the joint. As the pipe contracts the crimp opens and as the pipe expands the crimp closes. This joint is used in pipes of 36 inches to 108 inches in diameter.

It is well to reduce the number of joints by making the units as long as practicable, and each unit should be equipped with an expansion joint. Trench conditions, such as bracing and handling, will usually determine the practicable length to be about 8 feet.

Pipe are cast on end and the molds of sheet steel and cast iron must be erected on a substantial base or foundation of reinforced concrete, the surface of the foundations being truly level and finished so that when the cast iron base mold is set and the sheet steel casings are erected the casings will be truly vertical.

In the manufacture of most precast concrete pressure pipe, it is necessary to use 1 volume of Portland cement, 1½volumes of sand and 2½ volumes of coarse aggregate, and this means that 2½ barrels or 950 pounds of cement are used per cubic yard of concrete. In the manufacture of precast pipe for the Winnipeg Aqueduct it was found necessary to use but one sack of cement to 3.8 cubic feet of mixed aggregate, or approximately 2 barrels or 700 pounds of cement per cubic yard of concrete. (The Canadian barrel weighs 350 pounds gross or 346 pounds net.) This minimum quantity of cement was found practicable owing to the very excellent grading of the mixed aggregate which was supplied by the Greater Winnipeg Water District from its own pit at which was located a screening and remixing plant. The concrete is mixed to a quaking or jellylike consistency, which will easily flow to place when slightly puddled.

The mortar for spigots is made of 1 part cement to 2 parts sand and is mixed to the same consistency as the concrete so as to obtain the same rate of setting as nearly as possible. As the spigot mortar settles, more mortar is added until the settlement ceases, when the joint is finished.

Concrete pressure pipe may be successfully manufactured in cold weather with the proper appliances for supplying heat and moisture. In fact, where high speed of manufacture is desired, steam curing should be resorted to and this may be carried on regardless of temperature conditions. For the manufacture of large sizes, appropriate handling equipment and appliances should be provided, such as traveling derricks, locomotive cranes and light industrial tracks, cars and locomotives.

Good pipe under a test pressure of 50 pounds per square inch should show a leakage of only about 400 gallons per mile per 24 hours. This result can be secured by the use of well designed equipment, well graded aggregate, proper methods of manufacture and unremitting care.

The pipe line in Seattle was a trunk water conduit to operate under a head of 90 feet and every pipe was tested to 1½ times the working head. Tests were made on short sections of completed line and the leakage was nil.

In addition to the copper expansion joint type of concrete pressure pipe, there has recently been developed a new type of expansion joint which is very efficient. This joint is proposed for reinforced concrete pressure pipe in diameters of 10 to 48 inches and in lengths

of 12 feet, each section of pipe being provided with cast iron spigot ring at one end and a cast iron bell ring at the other, the rings being cast into the concrete.

The faces of the rings bear upon a lead gasket and are accurately machined providing a very true circular surface. The spigot ring is provided with a seat for the gasket, the object being to provide a greater thickness of gasket at the seat and to prevent the gasket being withdrawn when the pipe contracts or is deflected. The lead gasket consists of a thin lead pipe filled with fiber and is compressed into the space between bell and spigot when each succeeding length of pipe is shoved home. A light rope of cotton or jute is placed and a weak joint filler of cement mortar is applied, filling the caulking space. The joint has remained tight under test at 110 pounds pressure per square inch.

Tanks and standpipes. There are many examples of concrete standpipes of much greater height than 100 feet. The Fulton standpipe at Fulton, N. Y., is 100 feet high to overflow and is 40 feet in diameter. The circular concrete tower and tank at Middleboro, Mass., is 123 feet high. The concrete cylindrical tower and tank of the Central of Georgia Railway at Savannah is 188 feet high.

The supporting tower of elevated tanks may be either of concrete framework or of the cylindrical type. The latter has a number of advantages. The same forms may be used to construct the supporting tower as are used in the construction of the tank. These forms are moved upward as the concrete is being placed, thus giving a continuous monolithic concrete shell without any construction joints whatever. In addition to this particular advantage in construction the cylindrical tower furnished a housing for the riser pipe which protects it from low temperatures and may even be utilized for storage or office purposes.

In the design of concrete standpipes, as in the design of such structures of any material, the critical point is usually found in the junction of the shell with the base. The Fulton tank above referred to is an example of a successful method that has been used to take care of the expansion and contraction at the bottom of a standpipe shell due to variations in water level and temperature. The central portion of the foundation for this tank was constructed higher than the point of contact between the bottom of the shell and the foundation. Thus, space was formed between the inside of the shell and

the central raised portion of the foundation. This space was filled with an asphaltic material. The shell of the standpipe proper was not connected to the foundation but rested on a slip joint which allowed movement at the base of the shell to provide for change in the diameter of the standpipe due to variations in pressure. The

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top of the concrete foundation on which the shell rests was first covered with graphite paste and sheet copper laid immediately on top. The walls of the standpipe thus rest upon the sheet copper plate which is free to move on the graphite.

This standpipe was constructed with sliding forms and was completed from foundation to overflow in 52 working days. It has been in constant use since 1913 and has proved entirely satisfactory.

Filters. Concrete is particularly useful in the construction of mechanical filtration plants. At the Montebello plant at Baltimore, Md., for instance, about 50,000 cubic yards were used, most of which withstands water pressure or heavy loads. No waterproofing compounds were used in these structures, as good workmanship and materials were relied upon for securing waterproof work. Steel forms were used in the construction of the groined arches and walls and columns but were not found to be entirely satisfactory for columns and arches on account of difficulty in erecting and removing them. The steel forms for walls were entirely satisfactory. It is worth while to note in passing that at the present time steel forms are available for construction of this sort, which add a great deal to the ease with which it can be accomplished and the author feels quite sure that in the design of such a filtered water reservoir at the present time, a flat slab construction would be considered in place of the groined arches and that standard steel forms for columns and slabs would be used.

A feature of the head house of the Montebello filters is the elevated tower 4 feet square and 80 feet high containing the chemical storage bins. This tower has 15 bins which will hold about two carloads of chemicals each.

Pumping stations. The use of concrete in the construction of buildings of a general nature is too well known to need any particular comment. A pumping station, of course, has some special features required by the fact that it houses machinery and boilers. The building best adapted for this purpose is one which will be free from vibration, furnish adequate light and afford security against fire. These requirements are all met by concrete.

An interesting example of pump house construction is that recently completed for the city of Louisville, Ky. This station is located on the bank of the Ohio River just east of the city's old pumping station. As the structure had to rest on sand and gravel and as it was necessary to build the foundation so as not to affect the adjacent buildings, the open dredging well, caisson method was used. The outside dimensions of the caissons are 90 feet square by 33 feet deep, with a bay on the river side 61 by 22 feet and 33 feet deep. The interior cutting edges were 5 feet 2¼ inches above the outside cutting edges, thus allowing room for a working chamber in case obstructions were encountered, compelling conversion of the caisson from the open well to pneumatic type. However, this contingency did not arise

and the caisson was sunk to its final resting place without mishap. After filling the dredging wells, the foundation became a solid block of concrete, 90 feet square by 28 feet thick under the main house and 51 by 22 feet by 16 feet thick under the bay. On this foundation the substructure extending to the main floor level was built. This is 83 feet square at the bottom and tapers to 75 feet square at the main floor level, which is 7 feet, 6 inches above high water. The inside of this part of the structure is cylindrical, 67 feet in diameter, and forms the pump pit. The cylindrical pump pit walls were designed to resist external water pressure and the construction has resulted in an absolutely dry pump well.

No concrete shows on the face of the superstructure but back of the 6-and 9-inch ashlar surface is a concrete wall 30 inches thick, which in reality amounts to piers between the high windows and supports the runway girders for a 30-ton crane. Stone facing was used in order to make the new station as much like the old one as possible in external appearance.

Fuel oil tanks. There is now a marked tendency to use fuel oil in the place of coal for the generation of power. There are certainly many advantages to be derived from the use of this fuel. It does away with a considerable amount of the handling expense, leaves no ashes and cinders to be disposed of, and produces but relatively little smoke. Firing with fuel oil is a simple matter and effects economy in labor.

In order that fuel may always be available and that the purchasers of it may have the opportunity to take advantage of market conditions, storage capacity should be provided. The storage of fuel oil has been and is still subject to considerable discussion, especially in regard to the effect that the presence near buildings of such combustible material has on the fire hazard. It is the author's understanding that there is an almost universal practice to add a very heavy penalty because of the presence of fuel oil in open tanks above ground. This penalty, however, is not added when the oil is stored in concrete tanks below ground. There are further arguments for the underground storage tank. Such tanks do not occupy space near the power plant, which is usually needed for other purposes. They are entirely out of sight as well as protected against likelihood of fire from lightning or from other origin.

The design and construction of concrete oil tanks is little or not at all different from concrete water tanks. In fact, it is usual to

design them for ordinary hydrostatic pressures and experience shows that when well constructed, entire confidence may be placed in their ability to hold the oil without leakage. Naturally, where the surface of the tank is level with the ground surface and will have to carry loads, the cover must be designed accordingly and usually requires the use of columns which rest upon the tank bottom.

Actual bids on the cost of concrete tanks reveal the fact that even including the excavation and backfill, they are only slightly more expensive than the usual open surface steel tank. Of course, concrete tanks require no painting and may be considered as permanent and therefore practically free from any cost save first cost.